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# A Comparison of the Maximal Torque Production of the Quadriceps Muscle during Morning and Afternoon Strength Assessment

Shawn Dockter  
*University of North Dakota*

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A COMPARISON OF THE MAXIMAL TORQUE PRODUCTION  
OF THE QUADRICEPS MUSCLE DURING MORNING AND  
AFTERNOON STRENGTH ASSESSMENT

by

Shawn Dockter  
Bachelor of Science in Physical Therapy  
University of North Dakota, 1998

An Independent Study

Submitted to the Graduate Faculty of the

Department of Physical Therapy

School of Medicine

University of North Dakota

in partial fulfillment of the requirements

for the degree of

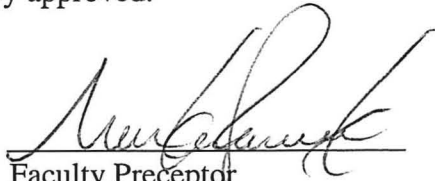
Master of Physical Therapy

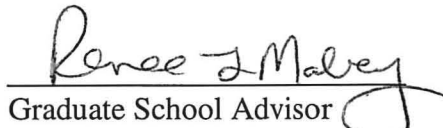
Grand Forks, North Dakota

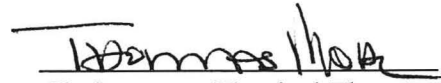
May  
1999



This Independent Study, submitted by Shawn Dockter in partial fulfillment of the requirements for the Degree of Master of Physical Therapy from the University of North Dakota, has been read by the Faculty Preceptor, Advisor, and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

  
Faculty Preceptor

  
Graduate School Advisor

  
Chairperson, Physical Therapy


## PERMISSION

Title           A Comparison of the Maximal Torque Production of the Quadriceps Muscle During Morning and Afternoon Strength Assessment.

Department   Physical Therapy

Degree       Master of Physical Therapy

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First, I would like to thank my parents for their support during my education. This paper is dedicated to them for all they have given me throughout my life. I love you both, Shawn.

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## ABSTRACT

The purpose of this study was to compare maximal quadriceps torque production between morning (AM) and afternoon (PM) hours. Thirty healthy male subjects between the ages of 21 and 43 were tested during an AM and PM session on the Kin-Com dynamometer. Six concentric isokinetic contractions of the right quadriceps were tested at a speed of 60°/s. The maximal peak torque measurements were compared between the AM and PM sessions to establish the validity of results taken at differing times of day. No significant difference in strength assessment due to time of day was found. The data collected in this study suggest clinical assessments of maximal peak torque production are not biased by time of day.

## CHAPTER 1

### INTRODUCTION

Physical therapists often use assessment of muscle strength to aid in clinical evaluations and decision making. Patients taking advantage of physical therapy services will often be assessed for strength multiple times before services are terminated. However, as scheduling may require, these assessments are not always performed at the same time of day. Circadian variations of strength have been reported in the literature, yet may not be taken into consideration when interpreting the results of strength testing.<sup>1-4</sup> It is often assumed changes in strength can be attributed to a change in the status of the patient. However, should evaluations be scheduled at different times of day, it is unclear whether strength differences are due to a change in the patient's status or due to the normal varying of strength throughout the day.

This study is designed to investigate the effects of circadian variation on strength assessments of the leg extensors via dynamometry. In the clinical setting, dynamometers are commonly used equipment during strength measurements. The goal of this study is to ascertain whether testing and retesting strength using dynamometry must be scheduled at the same time of day in order to obtain valid evaluations. Information gained in this study could warn therapists of possible inaccuracies with regards to scheduling evaluations and advise clinicians of the best scheduling practices.

This study attempts to answer some questions. First, is it necessary to schedule initial strength tests and subsequent retests at the same time of day? Also, is the amount of circadian strength change large enough between the average clinic hours of 8 AM to 5 PM to account for differences in strength testing?

The purpose of this study is to determine the significance of any difference in quadriceps strength between morning and afternoon. The null hypothesis states there is no difference between morning and afternoon peak leg extensor torques. The alternate hypothesis states there is a difference between morning and afternoon peak leg extensor torque.

## CHAPTER 2

### LITERATURE REVIEW

Assessment of muscle strength often aids clinicians during evaluations and decision making. Manual muscle testing, completed frequently by physical therapists, reveals approximate strength levels but is not sensitive enough to reveal small strength changes. Performance of functional tasks is often indicative of muscle strength but is hard to quantify. A popular form of strength testing that solves these problems involves the use of isokinetic exercise. A dynamometer is a common piece of equipment in the clinical setting that allows for the performance of isokinetic exercises and evaluations.

Isometric, isotonic, and isokinetic movements are three basic forms of muscle exercise. Isometric exercise occurs when the amount of resistance given is sufficient to prevent any movement at the involved joints and muscles. One common example is pushing against an immovable object, such as a wall. The main disadvantage of isometric exercise is that the exercised body segment is confined to one position along the arc of motion; the entire joint or muscle range is not exercised. Isotonic exercise consists of a muscular force being exerted against a constant unchanging resistance with changes in muscle length occurring. Traditional weight lifting is a form of isotonic exercise. One disadvantage of this form of exercise is that the amount of work the exercised muscles perform is submaximal. Since muscles are weaker in some joint

positions compared to others, the amount of resistance used in isotonic exercise is limited by the weakest part of the motion.<sup>5,6</sup>

Isokinetic exercise is different from isotonic and isometric exercise because it is the only form of exercise in which the speed of a muscular contraction is controlled while the muscle length is changing. This exercise form affords the advantage of maximal muscle performance throughout the entire range of motion and recruitment of the greatest number of motor units.<sup>7</sup> Because speed is constant regardless of the amount of force produced by involved muscles, resistance provided by the isokinetic device accommodates to the amount of force being produced.<sup>5</sup> In addition, the ability to control speed and exercise at different velocities affords training versatility. As the velocity of a contraction increases, the amount of force that can be generated by a muscle decreases.<sup>6</sup> Exercise at lower velocities, such as 30°/s or 60°/s, allows for the development of greater peak torques. Maximal exercise at slow isokinetic speeds allows for high resistance training. High velocities, such as 180°/s, require higher contraction speeds but yield lower peak torques when maximal performance is tested. These higher speeds are thought to simulate functional angular velocities.<sup>8</sup> The main disadvantage of isokinetic exercise is that it requires some form of external speed control, which is often in the form of expensive equipment.<sup>5</sup>

Clinically, objective measures of strength can be obtained when using dynamometry. For instance, the Kincom dynamometer uses an online computer to analyze and summarize exercise data, which can be reviewed by the clinician. This data is used to generate reports that often contain measures of peak torque and work performed throughout a specific range of motion. Often reports are generated before and



after training to evaluate its effectiveness. Clinicians may use these reports to quantify the amount of progress a patient has made. Also, reports comparing strength between a pathologic and nonpathologic limb can help when evaluating a patient's status.

When completing experiments, investigators attempt to develop methods that eliminate sources of error. However, in the clinical setting, it may be impractical to eliminate some of these sources. For instance, patients' activities prior to various tests could affect their performance during the evaluation. Someone who completes intense exercise prior to testing may show a decrease in performance due to fatigue. Once error is eliminated, the basic assumption is that any differences in the data reported from different testing sessions are solely due to differences in the patient's status. One source of error, the effect of circadian rhythms, is the focus of this investigation.

Chronobiology is the study of time-dependent changes of physiologic variables. One area of study deals with circadian rhythms, which refers to physiologic variables that follow a 24-hour cycle. Controls of circadian rhythms located outside the body, termed exogenous controls, include environmental stimuli and social behaviors. Daylight and changing shift work (working rotating shifts or overnight shifts) are two common exogenous controls that influence rhythms. Endogenous controls of circadian rhythms, commonly called biological or internal clocks, are located inside the body. The persistence of rhythms in unchanging or controlled environments is evidence endogenous controls exist. However, circadian rhythms do adapt to a change in the environment over a period of time via a process called masking. The paired suprachiasmatic nuclei, located just anterior to the hypothalamus, seem to be the most important endogenous pacemakers, though other centers of rhythmicity have been argued to exist.<sup>2</sup>

Many circadian rhythms have been discovered in various body systems, possibly affecting the ability of muscles to perform. Human body temperature is lowest between 4 and 6 AM, rises until between 4 and 9 PM, and then falls again. The average temperature change in young adults throughout the cycle has been reported between 0.5°C to 1.0°C.<sup>1,2,9</sup> A rhythm of cardiovascular measures including heart rate, blood pressure, stroke volume, cardiac output, and blood flow has been found that peaks near 3 PM. The rhythms for blood pressure and heart rate are highly influenced by exogenous controls such as sleep, posture, eating, and activity. Oxygen consumption has been shown to vary rhythmically and is theorized to be related to the body temperature rhythm. Rhythms for gastrointestinal functions such as motility patterns, absorption rates, gastric acids, and enzyme activity have been documented to peak during the daylight hours.<sup>2</sup> Other rhythms involving metabolic and pulmonary functions, psychological factors, excretory processes, and hormone levels display circadian variability.<sup>1-3,11</sup>

Performance of physical tasks is variable throughout the day.<sup>1</sup> As a general rule, muscle strength and performance is better in the afternoon or evening than in the morning.<sup>1-4</sup> The rhythm of muscular performance is theorized to be closely related to the body temperature rhythm, as it displays similar peaks and troughs.<sup>1-3,10</sup> Certain physiologic characteristics can explain why these two patterns relate so closely. Oxygen more easily dissociates from hemoglobin as temperature rises.<sup>13</sup> Increases in tissue temperatures cause increases in nerve conduction velocities and metabolic activities, as well as increases in blood flow to a warmed muscle.<sup>13,14</sup> For every 1°C rise in body temperature, nerve conduction velocity increases 2.4 m/s.<sup>2</sup>

The majority of components that pertain to performance, such as flexibility, strength, and power output, vary with time of day in a sinusoidal pattern.<sup>2</sup> Psychomotor performance, such as reaction times, exhibits a rhythm that peaks in the evening and is lowest in the overnight hours.<sup>2,15</sup> Flexibility of various joints exhibits a rhythm with a large interindividual difference, peaking anywhere between noon and midnight. Short term power output, such as vertical or horizontal leaping, also demonstrates a rhythm that peaks later in the day, though inappropriate research methods can easily mask this rhythm.<sup>2</sup>

Studies investigating the circadian variation of leg strength have previously been performed. Bernard et al<sup>16</sup> studied the effects of time of day on maximal anaerobic leg exercises. Subjects consistently scored higher on tests involving cycling and jumping when tested at 2 and 6 PM when compared to 9 AM. Scores in sprinting a 50 meter dash were also higher, but failed to reach significance. Reilly and Down<sup>9</sup> also studied the circadian effect on anaerobic capacities of the leg. They found a rhythm on stair running and broad jump tests but not in a Wingate anaerobic test. A study by Coldwells et al<sup>4</sup> measuring back and leg strength at different times of day found evidence of a strength rhythm. Back extensor and leg extensor strength peaked at 4:53 PM and 6:20 PM respectively. Wyse et al<sup>17</sup> performed an investigation with methods similar to this study, testing nine adult collegiate sportsmen three times a day (from 8 to 9 AM, 1 to 2 PM, and 6 to 7:30 PM) on three separate occasions. Testing consisted of isokinetic concentric measures at 60°/s and 180°/s for the knee flexor and extensor musculature. They found peak torque values for the knee extensor and flexor muscles gradually increased as the day progressed, but in general were significantly higher only during the 6 to 7:30 PM

testing session. In addition, they found the amount of testing error that occurred was consistent between the different times of day, suggesting tests at one time of day did not provide more accuracy than another time.

As noted earlier, strength testing in the clinical setting is common practice. Yet, as patient scheduling may require, testing isn't necessarily conducted at the same time of day for each evaluation. Also noted earlier, it is assumed any differences in clinical strength testing are due to differences in the patient's status. Since muscular performance is variable throughout the day, testing results may be called into question if evaluations are performed at differing times.

CHAPTER 3  
METHODOLOGY  
SUBJECTS

Thirty, healthy male subjects, between the ages of 21 and 43 volunteered to participate in this study. Fitness levels of the subjects were quite variable, with activity levels ranging from daily exercise to sedentary lifestyle. All subjects were currently enrolled as students at the University of North Dakota in Grand Forks, North Dakota. To participate in this study, each subject agreed to not participate in any lower extremity strengthening or aerobic exercise and activities for 1 day prior to each testing procedure. Volunteers excluded from this study included subjects with any neurological disorders and/or any leg or knee pathology within the last year. Also, subjects were excluded if they had any current knee dysfunction or muscle soreness/fatigue prior to the testing procedure. The subjects were randomly assigned to either an early morning (no longer than 1.5 hours after awakening from a 6 hour or longer sleep) test group or an afternoon (must have been awake for longer than 8 hours but less than 16 hours) test group. The AM and PM testing sessions were completed from 7:30 to 9:30 AM and 2:30 to 5 PM respectively. Participants were informed of the testing procedures and took part in a familiarization session with the researchers and equipment prior to testing. The volunteers were informed of their rights as a participant in accordance with the Institutional Review Board procedures at the University of North Dakota. As such, the

Institutional Review Board reviewed a copy of the University of North Dakota Human Subjects Review Form (Appendix A). Each subject signed an information and consent form prior to voluntary participation in the study (Appendix B).

## INSTRUMENTATION

The Kin-Com (model 125AP with software version 4.06, Chattecx Corp., Chattanooga, TN) dynamometer was used to evaluate peak torque values in this study. The reliability and validity of the Kin-Com to assess isokinetic torque during successive sessions has been established in several previous studies. Snow and Blacklin<sup>18</sup> found that within sessions, the interclass correlation coefficients (ICC) ranged from .94 to .98 for 30°/s and from .92 to .97 at 180°/s. Between sessions trials (1 week apart) ranged from .94 to .98 for 30°/s and from .75 to .88 for 180°/s. The data represent a higher reliability for slower speeds. In an analysis of the reliability and validity of the kinetic communicator exercise device by Farrell and Richards,<sup>19</sup> both static and dynamic tests resulted in a difference of 3.2% or less for force measurements. However, they felt this discrepancy was due to calibration error and not an indication of inaccuracy in the Kin-Com system. In addition, they found lever arm speed to be within 1.5% of the target speed and no discrepancy noted in position measurement. A study by Reitz et al<sup>20</sup> reported a correlation coefficient for the Kin-Com ranging from .95 to .98 for parameters of 60°/s, 120°/s, and 180°/s. The work of Tredinnick and Duncan<sup>21</sup> resulted in an interclass correlation coefficient for intertest reliability of concentric torque at 60°/s to be .89 and a coefficient of .85 for concentric work. Kues et al<sup>22</sup> suggest reliable measures of leg muscle performance can be made on the Kin-Com using a variety of consistent test protocols.

The Kin-Com dynamometer is a versatile machine, capable of testing both the upper and lower extremities, that can be set in either an evaluation mode or training mode.<sup>22</sup> In this study the right lower extremity concentric isokinetic contractions were tested in the evaluation mode. The range of motion (ROM) for the lever arm was set to an anatomical zero for each subject. From that point the machine was programmed to allow for motion of testing between 10° and 80°. The acceleration and deceleration settings of the Kin-Com lever arm at end range were set on high. The high settings allowed for the subject's limb to accelerate and decelerate from a constant velocity in the shortest possible time period, thus maximizing the amount of time the subject's limb moved at a constant velocity.<sup>22</sup> The velocity of the lever arm was set at 60°/s. This speed was selected due to reports from previous studies that suggest a high correlation coefficient (.89) for concentric torque at this speed.<sup>21</sup> This data is reinforced by Snow and Blaklin<sup>18</sup> who concluded slower speeds reveal a higher rate of reliability. In addition, this speed is commonly used in clinical settings during assessment.

## PROCEDURE

Four examiners administered the testing, with at least two present at each session. Prior to subject use, the team members conducted a training session and established a written protocol for testing procedure. All four individuals conducting the study strictly followed the protocol. It has been shown reliable measurements can be achieved by multiple examiners with variable isokinetic testing experience.<sup>23</sup>

Each subject was first oriented to the Kin-Com machine in a familiarization session 1 week prior to the actual testing procedure. Before being positioned on the Kin-Com, each subject warmed up on a Monark (Monark Exercise AB, Vansbro, Sweden)

stationary bike for a period of 2 minutes. Each subject's name, weight, and age were then recorded. Each subject was positioned on the Kin-Com to fit his specific physical dimensions. The subject's settings were saved during the familiarization session on the computer to ensure the exact position could be recalled for future testing procedures. Position settings for each subject were also established and recorded at this time following the protocol of the Kin-Com Basic Training Course Workbook. Each subject was tested in a seated position with two restraining belts around the trunk and one restraining belt around the waist. Each subject's right knee rotational axis was aligned with the dynamometer's axis of rotation using the femoral epicondyles as the center. The subject's right lower leg was then secured to the dynamometer arm with a double shin pad and the right thigh was stabilized with a restraining pad. At this time, the subject was instructed to perform six submaximal concentric contractions of the quadriceps and to relax all musculature on the return of the dynamometer arm to the flexed position after each repetition. After a rest period of 2 minutes, the subject performed six maximal repetitions of knee extension. Concentric isokinetic testing was performed at 60°/s to test the maximal quadriceps torque between the ROM of 10° and 80° of knee flexion. At this time in the familiarization session, the subject was asked if he was comfortable with the Kin-Com machine and the testing process. The set of six repetitions was repeated if the subject was uncomfortable with the process. If the subject felt comfortable, the session ended. He was then scheduled for a testing time no less than 3 days from the familiarization session.

All subjects were randomly assigned to 1 of 2 groups with 15 subjects in each group. The first group was initially tested in the early morning. The second group was



initially tested in the afternoon. The groups were then retested in the opposing time slot following a minimum of 3 days between tests. The testing procedure followed the same format as the familiarization session with a warm up on the stationary bike, a submaximal set of six concentric knee extensions, and the recorded maximal set of six contractions.

### DATA ANALYSIS

Data analysis was completed using the SPSS 7.5 for Windows and Microsoft Excel 97 for Windows programs. The right quadriceps muscle of each subject was measured for the highest peak torque during a set of six concentric isokinetic contractions at 60°/s. These values were identified using the Kin-Com software. The highest peak torque value for each test, one for the AM session and another for the PM session, were recorded for each subject. The group mean, standard deviation, and range were determined for each test session. Ratios comparing the AM and PM session were also analyzed. Descriptive statistical methods were used to describe the data with the use of a t-test for paired samples. In addition, Pearson's Correlation analysis was performed. All of the above data interpretations were analyzed for the entire sample and for two groups. Group I consisted of 15 subjects who participated in an AM session for their first recorded trial. Group II consisted of 15 subjects who participated in a PM session for their first recorded trial. Appendix C contains additional subject data. Individual test scores, body weights, and difference scores (PM-AM) are presented along with calculated means. Difference score standard deviation is also noted.

## CHAPTER 4

### RESULTS

As mentioned in the Methodology, the subjects performed two separate recorded trials, one in the AM and one in the PM. The maximal peak torque value (ft-lb) for each subject was determined by the highest torque produced during each six repetition trial at 60°/s. The mean value for the maximal peak torque production in the AM trials was 185.1 ft-lb. The mean value for the maximal peak torque production in the PM trials was 186.6 ft-lb. For the group (n=15) who performed their first recorded trial in the AM, Group I, the mean value of maximal torque production in the AM was 184.6 ft-lb and 181.6 ft-lb in the PM. The mean value of maximal torque production for the group (n=15) who performed their first recorded trial in the PM, Group II, was 185.7 ft-lb in the AM and 191.7 ft-lb in the PM. Additional data is presented in Table 1.

Table 1. – Mean Maximal Peak Torque Values for the Entire Sample and Two Separate Groups							
Sample	Mean (ft-lb)		Standard Deviation		Range (ft-lb)		AM / PM Ratio
	AM	PM	AM	PM	AM	PM	
Entire Sample (n=30)	185.1	186.6	35.6	41.1	122-273	123-286	0.99
Group I (n=15)	184.6	181.6	31.3	38.9	122-241	129-249	1.02
Group II (n=15)	185.7	191.7	40.6	43.9	129-273	123-286	0.97

The AM / PM ratios indicate that there was no significant difference between the two trial times as they all are nearly a 1:1 ratio. This data is reinforced by the use of a t-test for paired samples which revealed that the mean peak torque values were not significantly different for the sample ( $t(29) = -.46, p < .05$ , two-tailed). In addition, Group I ( $t(14) = +.52, p < .05$ , two-tailed) and Group II ( $t(14) = -2.14, p < .05$ , two-tailed) both failed to display any significant difference between tests performed in the AM and the PM. Data from the t-test for paired samples is presented in table 2.

Table 2. – T-Test for Paired Samples Results for the Entire Sample and Two Separate Groups	
Sample	t
Entire Sample (n=30)	-0.46
Group I (n=15)	+0.52
Group II (n=15)	-2.14

Calculations using the Pearson's Correlation revealed extremely high coefficients. The correlations ranged from .82 to .97. Table 3 contains the correlations between AM and PM sessions for the entire sample as well as for each group.

Table 3. – Pearson Correlation Values for the Entire Sample and Two Separate Groups	
Sample	Correlation Value
Entire Sample (n=30)	0.90
Group I (n=15)	0.82
Group II (n=15)	0.97

Appendix B contains descriptive data for each individual subject and additional data for the entire group. Individual body weights are presented with a mean of 179 lb. Results for each testing session and difference scores (PM-AM) are noted, with the difference scores mean and standard deviation of being 1.5 lb and 17.5 lb respectively.

## CHAPTER 5

### DISCUSSION

The results of this study suggest that a significant circadian variation in quadriceps strength does not exist between the AM and PM testing sessions. Though the mean force output for the entire sample was higher in the afternoon session, the amount of rise was small and failed to reach statistical significance. The peak torque rise of 1.5 ft-lb for our sample between the AM and PM tests was only 0.8% of the AM mean of 185.1 ft-lb, suggesting very little strength change had taken place. The AM/PM ratio of 0.99 also indicates the amount of change in torque measurements was extremely small.

The results of this study generally agree with previous studies on circadian strength variations. When Wyse et al<sup>17</sup> completed similar investigations on quadriceps circadian variability, they also found that although the mean force output did increase throughout the day, the amount of rise was small and failed to reach statistical significance between morning and afternoon tests (8 to 9 AM and 1 to 2 PM, respectively). In addition, the Pearson correlation coefficient obtained in this study (.90) is comparable to the coefficient obtained by Tredinnick and Duncan<sup>21</sup> (.89). However, their tests were completed at the same time of day. The fact that a nearly identical result was obtained suggests testing at different times of the day had minimal effect.

Isokinetic evaluation is a skill that must be learned by evaluator. Though the four examiners had minimal experience in isokinetic testing, steps were taken to reduce error

incurred in administration of the measurements. As noted earlier, the examiners completed a training session, established a written protocol, and completed tests with two examiners present for every session. Also noted earlier, reliable results can be obtained by multiple examiners with variable isokinetic testing experience. Keskula et al<sup>23</sup> obtained a correlation coefficient of .96 when four examiners with between zero and 10 years of isokinetic testing experience completed examinations. However, this study was conducted by four examiners, all with less than 1 year of isokinetic testing experience. Since a lower correlation coefficient was obtained in this study (.90), it appears testing experience favorably affects the accuracy of the results. Future studies with experienced examiners are encouraged.

Isokinetic exercise is also a task that must be learned by the performer. Previous investigation indicates subjects reach their highest torque levels between the second and third testing session. In addition, testing correlation coefficients are higher when comparing the second and third sessions as opposed to the first and second or first and third sessions. This phenomena is considered a learning effect.<sup>22</sup> This information influenced the methods of this study, with measurements being recorded on the second and third sessions on the Kin-Com. Yet, it is interesting to note both Group I and II reached their maximum peak torques on the second session and declined on their third (184.6 ft-lb versus 181.6 ft-lb for Group I, 191.7 ft-lb versus 185.7 ft-lb for Group II). Again it appears factors other than time of day had an effect on the results of this study. In order to minimize the learning effect, future studies are encouraged to use subjects with considerable isokinetic training experience.

In this study, the amount of verbal encouragement during testing was not strictly controlled. It has been shown verbal encouragement increases peak torque values.<sup>24</sup> Without these strict controls, the environment was more conducive to increased torque values during tests in which greater amounts of encouragement were given. Future studies should control this variable to obtain more valid results.

It is interesting to note that although the mean for the entire sample changed minimally between the AM and PM sessions, many individuals had large changes in peak torque between the sessions. Although the mean torque difference was only 0.8% of the AM mean, the difference score standard deviation of 17.5 lb is 9.5% of the AM mean. While the population as a whole may not exhibit much strength change between AM and PM sessions as conducted in this study, individuals may demonstrate large gains or losses in torque scores in a clinical trial. People within two standard deviations, assumed to be 95% of the population, could have difference scores in test/retest situations of +/-35 ft-lb. Clinicians should be cautioned against assuming individuals will have similar test/retest scores. This high variability for an individual is probably attributed to the fact that only one trial was used for each person during each testing session. Multiple trials for every individual are suggested in order to gain more accurate strength assessments in the clinic and during experimentation.

Clinically, it appears isokinetic quadriceps testing and subsequent retesting need not be completed at the same time of day if completed between 7:30 AM and 5 PM. Though individual difference scores may be large, as noted above, these differences appear to be due to factors other than circadian variation.

## CHAPTER 6

### CONCLUSION

The goal of this study was to examine the effect of circadian strength change on the quadriceps muscle. Circadian strength change has been documented in literature and performance of physical tasks appears to improve as the day progresses. In order to measure the circadian effect, concentric quadriceps peak torque measurements of 30 subjects were gathered on a Kin-Com dynamometer during an AM and PM testing session. Comparing torque scores revealed mean strength did increase, but did not reach statistical significance. The results of the study suggest circadian strength change played a minimal role between AM and PM testing.

The data suggest circadian variation will not play a role in isokinetic testing and retesting during normal clinic hours of 8 AM to 5 PM. Clinicians need not schedule tests and retests at the same time of day in order to obtain valid results. However, clinicians are cautioned against assuming test/retest scores will have minimal variation.

Future studies investigating circadian effects of isokinetic strength are encouraged to use subjects with considerable training experience on isokinetic devices. Likewise, administering examinations by those experienced in isokinetic evaluation is suggested for future experiments. Multiple trials are also suggested to lower the variability of scores.



APPENDIX A

UNIVERSITY OF NORTH DAKOTA HUMAN SUBJECTS REVIEW FORM FOR  
NEW PROJECTS OR PROCEDURAL REVISIONS TO APPROVED PROJECTS  
INVOLVING HUMAN SUBJECTS

☒ **EXPEDITED REVIEW REQUESTED UNDER ITEM 3 (NUMBER[S]) OF HHS REGULATIONS**  
☐ **EXEMPT REVIEW REQUESTED UNDER ITEM \_\_\_\_\_ (NUMBER[S]) OF HHS REGULATIONS**

**UNIVERSITY OF NORTH DAKOTA HUMAN SUBJECTS REVIEW FORM  
FOR NEW PROJECTS OR PROCEDURAL REVISIONS TO APPROVED  
PROJECTS INVOLVING HUMAN SUBJECTS**

**PRINCIPAL**

**INVESTIGATOR:** Shawn Dockter, Shawn McCoul, Michael Rexin, Denise Willardsen

**TELEPHONE:** (701)-777-9485 **DATE:** 2/11/98

**ADDRESS TO WHICH NOTICE OF APPROVAL SHOULD BE SENT:** 3904 University Ave. #16,  
Grand Forks, ND 5820

**PROPOSED SCHOOL/COLLEGE:** University of North Dakota **DEPARTMENT:** Physical Therapy

**PROJECT DATES:** 3/1/98-12/18/98 **PROJECT TITLE:** A Comparison of the Maximal Torque Production of the Quadriceps Muscle During Morning and Afternoon Strength Assessment.

**FUNDING AGENCIES (IF APPLICABLE):** \_\_\_\_\_

**TYPE OF PROJECT (Check ALL that apply):**

☒ **NEW PROJECT** ☐ **CONTINUATION** ☐ **RENEWAL** ☐ **DISSERTATION OR THESIS RESEARCH** ☒ **STUDENT RESEARCH PROJECT**

☐ **CHANGE IN PROCEDURE FOR A PREVIOUSLY APPROVED PROJECT**

**DISSERTATION/THESIS ADVISER, OR STUDENT ADVISER:** Mark Romanick

**PROPOSED PROJECT:** ☐ **INVOLVES NEW DRUGS (IND)** ☐ **INVOLVES NON-APPROVED USE OF DRUG** ☐ **INVOLVES A COOPERATING INSTITUTION**

**IF ANY OF YOUR SUBJECTS FALL IN ANY OF THE FOLLOWING CLASSIFICATIONS, PLEASE INDICATE THE CLASSIFICATION(S):**

☐ **MINORS (<18 YEARS)** ☐ **PREGNANT WOMEN** ☐ **MENTALLY DISABLED** ☐ **FETUSES** ☐ **MENTALLY RETARDED**  
☐ **PRISONERS** ☐ **ABORTUSES** ☒ **UND STUDENTS (>18 YEARS)**

**IF YOUR PROJECT INVOLVES ANY HUMAN TISSUE, BODY FLUIDS, PATHOLOGICAL SPECIMENS, DONATED ORGANS, FETAL MATERIAL, OR PLACENTAL MATERIALS, CHECK HERE** \_\_\_\_\_

**IF YOUR PROJECT HAS BEEN WILL BE SUBMITTED TO ANOTHER INSTITUTIONAL REVIEW BOARD(S), PLEASE LIST NAME OF BOARD(S):**

Status: ☐ **Submitted; Date** \_\_\_\_\_ ☐ **Approved; Date** \_\_\_\_\_ ☐ **Pending**

**1. ABSTRACT: (LIMIT TO 200 WORDS OR LESS AND INCLUDE JUSTIFICATION OR NECESSITY FOR USING HUMAN SUBJECTS.)**

The purpose of this study is to compare maximal quadriceps torque production in morning hours to maximal quadriceps torque production in afternoon hours.

Twenty-five to fifty male subjects will take part in this study. A maximum torque will be assessed with a Kin-Com isokinetic machine to compare the amount of quadriceps torque produced in early morning hours as compared to afternoon hours. Each subject will be randomly placed in one of two test groups. The first group will be initially tested in the morning. The second group will be initially tested in the afternoon. The groups will be re-tested in the opposing time slot after at least three days have passed. A comparison will then be made between quadriceps torque production in the morning and afternoon.

The significance of this study is to determine if the time of day affects maximal torque production of the quadriceps muscle. The results may be applied to clinical objective testing procedures and may help with development of the most efficient strengthening schedules.

**PLEASE NOTE:** Only information pertinent to your request to utilize human subjects in your project or activity should be included on this form. Where appropriate attach sections from your proposal (if seeking outside funding).

**2. PROTOCOL:** (Describe procedures to which humans will be subjected. Use additional pages if necessary.)

**Subjects:** Twenty-five to fifty male subjects between the ages of 19 and 45 will participate in this study. They will be randomly assigned into a morning (no longer than 1.5 hours after awakening from a 6 hour or longer sleep) training group and an afternoon (must be awake for longer than 8 hours but no more than 16 hours) training group. All subjects will complete a consent form in accordance with the University of North Dakota Human Subjects Review Committee.

*Exclusion criteria* will consist of the following: 1) subjects who have had a history of neurological disorders or previous leg/knee trauma within the last year or have current knee dysfunction, 2) subjects who report any muscle fatigue or weakness due to activity prior to the testing time.

**Instrumentation:** The equipment used to perform the testing will consist of a Kin Com AP (Chattanooga Corp., Chattanooga, TN). The Kin Com AP is a commonly used exercise machine which is capable of measuring muscle strength through peak torque values. The warm up will be performed on a stationary bicycle provided by the Physical Therapy department.

**Procedures:** Before the testing begins, all of the subjects will experience a trial-run of quadriceps torque measure to familiarize the subject with the nature of the testing procedure. At this time, the parameters of the Kin-Com machine will be set and recorded for each individual.

On the first day of testing, the maximum torque production of each subject's right quadriceps muscle will be assessed to determine the strength level of each subject. The subject will begin by performing a two minute warm-up on a stationary bicycle. A preliminary warm-up set will be performed to re-familiarize the subject with the testing procedure. The subject will then complete a concentric knee extension (type of exercise in which the muscle shortens while the force is being exerted) test consisting of 6 repetitions at sixty degrees per second. The results of this test are recorded by a dynamometer and stored in the computer's data base.

The subjects will be re-tested at the opposite time of their initial test following the same procedure as previously stated.

**3. BENEFITS:** (Describe the benefits to the individual or society.)

The benefits of this study will determine if maximal torque production of the quadriceps muscle is affected by the time of testing. This may broadly be applied to strength assessment of other muscles. If significant variations do exist between time of day and torque production, then clinicians must take into account time of day when testing and re-testing. From this data, further studies may be conducted to compare training times for optimal strength gains and athletic performance.

**4. RISKS:** (Describe the risks to the subject and precautions that will be taken to minimize them. The concept of risk goes beyond physical risk and includes risks to the subject's dignity and self-respect, as well as psychological, emotional or behavioral risk. If data are collected which could prove harmful or embarrassing to the subject if associated with him or her, then describe the methods to be used to insure the confidentiality of data obtained, including plans for final disposition or destruction, debriefing procedures, etc.)

Although any exercise poses certain minimal risks, our study is designed to further minimize these risks. Some precautionary measures include: 1) Instructions will be provided to the subject to terminate the procedure if at any time he is uncomfortable or experiences pain and will be provided a stop button ("kill switch") which will immediately stop the procedure. 2) A two minute warm up on a stationary bicycle will be performed to adequately prepare the muscles for activity. 3) A warm-up test set will be performed to further familiarize and prepare the subject for the test. 4) The Kin-Com machine is also equipped with electronic and mechanical stops to prevent movements outside of each subjects physiological range of motion (ROM). Although we have taken every measure to prevent risk, the remote possibility remains for a musculoskeletal injury, such as muscle strain.

5. **CONSENT FORM:** A copy of the **CONSENT FORM** to be signed by the subject (if applicable) and/or any statement to be read to the subject should be attached to this form. If no **CONSENT FORM** is to be used, document the procedures to be used to assure that infringement upon the subject's rights will not occur.

Describe where signed consent forms will be kept and for what period of time.

The enclosed consent form will be signed by each subject involved in this study. The forms will be kept in the University of North Dakota Physical Therapy department in locked filing cabinets. The only access to these cabinets will be to the examiners, the student advisor, Mark Romanick, and the head of the Physical Therapy department, Thomas Mohr, P.T. PH.D. The forms will be kept on file for a period of 3 years after the last day of experimental study involving the subjects. The data collected and stored on the Kin Com AP computer is kept behind locked doors in the Physical Therapy department.

6. For **FULL IRB REVIEW** forward a signed original and thirteen (13) copies of this completed form, and where applicable, thirteen (13) copies of the proposed consent form, questionnaires, etc. and any supporting documentation to:

Office of Research & Program Development  
University of North Dakota  
Grand Forks, North Dakota 58202-7134

On campus, mail to: Office of Research & Program Development, Box 7134, or drop it off at Room 105 Twamley Hall.

For **EXEMPT** or **EXPEDITED REVIEW** forward a signed original and a copy of the consent form, questionnaires, etc. and any supporting documentation to one of the addresses above.

The policies and procedures on Use of Human Subjects of the University of North Dakota apply to all activities involving use of Human Subjects performed by personnel conducting such activities under the auspices of the University. No activities are to be initiated without prior review and approval as prescribed by the University's policies and procedures governing the use of human subjects.

**SIGNATURES:**

Principal Investigator

Project Director or Student Adviser

Training or Center Grant Director

\_\_\_\_\_  
Date  
\_\_\_\_\_  
Date  
\_\_\_\_\_  
Date

(Revised 3/1996)

**STUDENT RESEARCHERS:** As of June 4, 1997 (based on the recommendation of UND Legal Counsel) the University of North Dakota IRB is unable to approve your project unless the following "Student Consent to Release of Educational Record" is signed and included with your "Human Subjects Review Form."

### STUDENT CONSENT TO RELEASE OF EDUCATIONAL RECORD<sup>1</sup>

Pursuant to the Family Educational Rights and Privacy Act of 1974, I hereby consent to the Institutional Review Board=s access to those portions of my educational record which involve research that I wish to conduct under the Board=s auspices. I understand that the Board may need to review my study data based on a question from a participant or under a random audit. The study to which this release pertains is

A Comparison of the Maximal Torque Production of the Quadriceps Muscle  
During Morning and Afternoon Strength Assessment.

I understand that such information concerning my educational record will not be released except on the condition that the Institutional Review Board will not permit any other party to have access to such information without my written consent. I also understand that this policy will be explained to those persons requesting any educational information and that this release will be kept with the study documentation.

\_\_\_\_\_  
Date

\_\_\_\_\_  
Signature of Student Researcher

<sup>1</sup> Consent required by 20 U.S.C. 1232g.

APPENDIX B

STATEMENT OF INFORMATION AND CONSENT

## INFORMATION AND CONSENT FORM

**TITLE:** A Study on the Maximal Torque Production of the Quadriceps Muscle During Morning and Afternoon Strength Assessment

You are being invited to participate in a study conducted by Shawn Dockter, Shawn McCoul, Michael Rexin, and Denise Willardsen, physical therapy students and Mark Romanick, a physical therapy instructor at the University of North Dakota. The purpose of this study is to determine if the time of day affects maximal torque production of the quadriceps muscle, by comparing maximal torque production in the morning and in the afternoon.

You will be asked to exercise on the Kin Com AP machine on 3 occasions – one familiarization session, one morning session, and one afternoon session. The Kin Com AP is a commonly used exercise machine which is capable of measuring muscle strength through peak torque values. At these sessions, you will be asked to perform a 2 minute warm-up on a stationary bicycle before being tested. You will then be required to perform maximum effort knee extensions while a computer records the amount of torque produced.

The study will take approximately 15-30 minutes of your time per session. You will be asked to report to the Physical Therapy Department at the University of North Dakota at an assigned time. You will then be asked to change into gym shorts for the experiment. We will first record your age, height and weight. During the experiment, we will be recording the amount of maximal torque production for your quadriceps muscles.

Although the process of physical performance testing always involves some degree of risk, the investigators in this study feel that the risk of injury or discomfort is minimal. In order for us to record the muscle torque, we will require you to exert your maximal force during an isokinetic knee extension movement on three separate days. One session will be for training purposes and the other two sessions will be for data collection. The data collection sessions will require you to participate in one morning and one afternoon session. For these sessions, you will be asked to perform a two minute warm up on a stationary bicycle, followed by the testing procedure consisting of 6 maximal efforts of knee extension. The amount of exercise you will be asked to perform will be minimal.

Your name will not be used in any reports of the results of this study. Any information that is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission. The data will be identified by a number known only by the investigator. The investigator or participant may stop the experiment at any time if the participant is experiencing discomfort, pain, fatigue, or any other symptoms that may be detrimental to his health. Your decision



whether or not to participate will not prejudice your future relationship with the Physical Therapy Department or the University of North Dakota. If you decide to participate, you are free to discontinue participation at any time without prejudice.

The investigator involved is available to answer any questions you have concerning this study. In addition, you are encouraged to ask any questions concerning this study that you may have in the future. Questions may be asked by calling Mark Romanick at (701)-777-2831. A copy of this consent form is available to all participants in the study.

In the event that this research activity (which will be conducted at the University of North Dakota in the Physical Therapy Department) results in a physical injury, medical treatment will be available, including first aid, emergency treatment and follow up care as it is to member of the general public in similar circumstances. Payment for any such treatment must be provided by you and your third party payment, if any.

**ALL OF MY QUESTIONS HAVE BEEN ANSWERED AND I AM ENCOURAGED TO ASK ANY QUESTIONS THAT I MAY HAVE CONCERNING THIS STUDY IN THE FUTURE. MY SIGNATURE INDICATES THAT, HAVING READ THE ABOVE INFORMATION, I HAVE DECIDED TO PARTICIPATE IN THE RESEARCH PROJECT.**

I have read all of the above and willingly agree to participate in this study explained to me by Shawn Dockter, Shawn McCoul, Michael Rexin, Denise Willardsen or Mark Romanick.

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Participant's Signature

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Date

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Witness (not the scientist)

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Date

APPENDIX C

INDIVIDUAL SUBJECT DATA

Subject	PM Score	AM Score	PM - AM	Subject Body Weight
1	129	122	7	148
2	146	177	-31	150
3	203	188	15	160
4	138	169	-31	225
5	134	162	-28	176
6	209	208	1	175
7	157	185	-28	210
8	215	211	4	174
9	185	167	18	165
10	249	220	29	210
11	219	241	-22	183
12	190	200	-10	145
13	240	232	8	205
14	221	213	8	200
15	151	164	-13	250
16	162	153	9	150
17	239	221	18	171
18	172	169	3	170
19	160	168	-8	177
20	286	273	13	210
21	168	174	-6	180
22	157	145	12	168
23	231	194	37	178
24	214	223	9	180
25	123	129	-6	150
26	152	157	-5	160
27	154	139	15	160
28	210	197	13	174
29	216	210	6	183
30	169	143	26	185
Mean	186.6	185.1	1.5	179.1
Standard Deviation			17.5	

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